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CLIMATE CHANGE AND GULLY EROSION IN THE DERIVED SAVANNA OF SOUTH-EASTERN NIGERIA

NWAGBARA, M.O.[1], CHIMA, G.N[2] & NDUKWE- OKOYE, N[3]

[1]Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

[2]Department of Geography and Planning, Abia State University, Uturu, Abia State, Nigeria

[3]Agro-Met Unit, National Root Crop Research Institute, Umudike, Abia State, Nigeria

ABSTRACT

The northern Fringes of the Tropical Rainforest (High Forest) vegetation in South-Eastern Nigeria are steadily being degraded into derived Savanna thereby exposing the soil to erosion, especially the gully type. This feature is not only increasing in occurrence but also in magnitude. The possibility of climate change playing a role in this has not been given the deserved attention. This paper therefore examined the extent the climate of South-Eastern Nigeria is changing and its implication in soil erosion occurrence and magnitude. Data on annual rainfall, and maximum and minimum temperatures for two stations namely Enugu (for 30 years) and Umuahia (for 34 years), and locations and magnitude of gully erosion sites in the study area were collected and analyzed. The linear regression statistic was employed in modelling the trends in the rainfall and temperature data for each of the two stations. Results showed an upward trend in annual mean temperature for Enugu (0.02^0C) and Umuahia (0.03^0C). Similarly, Enugu is getting wetter by 5.84mm while Umuahia is increasing by 5.25mm per annum. The implication of these results is that with the increasing population of South-Eastern Nigeria more areas might be turned into derived Savanna which will be extension mean more gullies in the face of increasing rainfall and temperatures. It is therefore suggested that there should be concerted efforts by governments at all levels and individual in Nigeria in checking this trend in gully erosion.

KEYWORDS: Climate Change, Trends, Soil Erosion, and Derived Savanna

INTRODUCTION

In a system, there is often the tendency for its components to respond to perturbation whether from within or from without. Climate, itself a system, is never static because of some internal and external perturbations (Meyer, 1996; Danielson *et al*., 1998; and Pidwirny, 2004). Similarly, the bigger earth-atmosphere system to which climate belongs is never stable due to its components that are ever changing. As climate is caused to change, other components of the earth-atmosphere system (soil and vegetation for example) might respond to influences exerted on them by the change. The current climate change is an issue that has capture not only the interests of researchers but also those of people, nations and governments the world over. Presently it is one of the most actively investigated scientific issues because of its potentially far-reaching consequences (IPCC, 1996; Danielson *et al*., 1998). Among these consequences are massive flooding, heavy storms and runoff, frequent and prolonged droughts, and increased sea temperature. The implications of these for man are enormous (Linacre, 1992; Obasi, 1992).

The present climate change via warming has been linked with change in the concentration of atmospheric gases particularly the ones termed "greenhouse gases" with carbondioxide being the major candidate. Others include water

vapour, chlorofluorocarbons (CFCs), methane, tropospheric ozone and nitrous oxide. These gases trap terrestrial radiation (which is in long wave length and contains mainly infrared rays) that would normally be radiated onto the upper atmosphere but instead is re-radiated earthward, thereby promoting atmospheric warming (IPCC, 2007).

The on-going warming has not been globally uniform. So also are its manifestations. For example, for some regions, the rising temperature has increased their rainfall levels while it has reduced the levels for some other regions, thus making some areas wetter and others drier. Though the tropics, within which the study area South-Eastern Nigeria- is located, is being the lest warmed in the present warming of the world (Meyer, 1996), any warming at all still makes it an area of very high temperature which could cause an increase in rainfall levels or a reduction in them. Vegetation and soil are some of the components of the earth-atmosphere system that might be affected by this because an increased rainfall implies more luxuriant growth for vegetation while a reduction in it especially in combination with raised temperature brings about withering of vegetation. On the other hand, an increase in rainfall portends an increase in soil erosion, where exposed, and a decrease in it could result in the drying up of the soil, thus making it (i.e the soil) more erodible as the particles become more detached. Consequently, this paper examines the extent the climate of South-Eastern Nigeria is changing and its implication in gully erosion occurrence and magnitude.

STUDY AREA

The very location of South-Eastern Nigeria between latitudes $4^0$10’ and $7^0$08’N and longitudes $5^0$30’ and $9^0$27’E (Figure 1) makes it a region of relatively high temperatures all year round. This is for both maximum and minimum temperatures, thus making the range between them to be very small if compared with that of northern Nigeria. The mean daily maximum temperature is usually above 27^0C all through the year. It is highest from February to April but rarely goes above 35^0C. Both the mean daily maximum temperature increase from its South towards the north attributable to the moderating effect of the Atlantic Ocean in the South. On the other hand, the mean daily minimum temperature decreases from the coast towards the interior and does not usually fall below 18^0C except in December and January when the effect of the cold harmattan winds is felt (Monanu, 1975) and most nights cloudless.

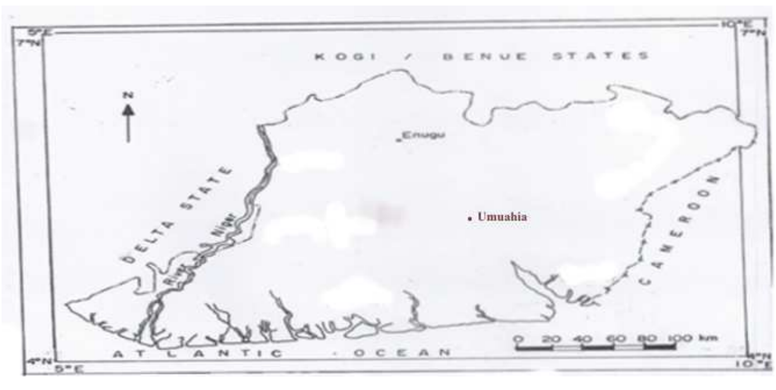


Figure 1: Study Area: South-Eastern Nigeria and Meteorological Station Used

The rainfall of South-Eastern Nigeria is influenced by the interaction between the Tropical Continental (cT) and the Tropical Maritime (mT) airmasses. The extent of the influence of each one of them is controlled by the position of the Inter-Tropical Discontinuity (ITD). This discontinuity moves forth and back over the region and thus determining which of the airmasses takes pre-eminence in exhibiting its characteristics over it. While the mT brings rain based on its source region, the Atlantic Ocean, the cT triggers off dry season with Harmattan embedded in it due to its dry and dusty nature

having come from the Sahara Desert. Thus, this makes the south wetter than the north. The annual rainfall total ranges between 1500mm, at the northern part of the region, to 4000mm at the extreme South.

Vegetation of South-Eastern Nigeria closely follows that rainfall pattern of the region. The dominant vegetation type is the tropical rainforest. The Guinea Savanna exists in the northern fringes of the region. Climate equally has a hand in the soils of the region as the colour of the soils is as a result of climatic conditions. Generally, the soils are heavily leached, reddish brown and sandy. The population of South-eastern Nigeria that grew from 18,921,872 persons in 1991 (National Population Commission (NPC), 1996) to 30,079,661 in 2006 (NPC, 2006) has got its own effect too on the vegetation and soils of the region with a land area of about 75,488 sq km (Ofomata, 1975a).

MATERIALS AND METHODS

The following data were employed for this study: (i) Annual rainfall amounts, and (ii) maximum and minimum temperature for two stations namely; Enugu (30 years) and Umuahia (34 years) and (iii) locations and magnitude of gully erosion sites in South-Eastern Nigeria. The linear regression statistic was employed in modelling the trends in the rainfall and temperature data for each of the 2 stations. Equally, the problem of missing values, where it existed, was resolved by the application of linear regression by which known values in the series were used to determine the unknown ones (Hammond and McCullagh, 1978). It is expressed in the form.

$$Y = a + bx \quad (1)$$

Where $b = \underline{n\Sigma xy - (\Sigma x)(\Sigma y)}$

$$n\Sigma x^2 - (\Sigma x)^2 \quad (2)$$

$$a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n} = \bar{y} - b\bar{x} \quad (3)$$

A is the intercept; b the regression coefficient or slope; y the temperature/rainfall values; x the time in years; $\bar{x}$ the mean time; and $\bar{y}$ the mean temperature/rainfall valued.

RESULTS AND DISCUSSIONS

Temperature and Rainfall Trends in South-Eastern Nigeria

Temperature and rainfall are good indicators of climate change (Nwagbara, 2008 and Uguru *et al.*, 2011) and their trends, a key word in this paper is a term commonly used in climatic studies to describe a general increase or decrease in climatic phenomena over time. It could equally be taken as part of a long term fluctuations (Jackson, 1977). The trends in the annual mean temperatures and the annual rainfall totals of Enugu and Umuahia are presented in Tables 1 and 2 and Figures 2, 3, 4 and 5. The two stations possess positive trends in their annual rainfall totals and annual mean temperatures. This implies that all the stations have upward trends in both parameters, in other words, the stations are getting warmer and wetter, over the study period. While the annual mean temperature of Enugu is increasing by 0.02^0C, that of Umuahia is increasing by 0.03^0C per annum. In the case of annual rainfall totals, Enugu is getting wetter by 5.84mm while Umuahia is doing so by 5.25mm per annum.

Table 1: Intercepts, Slopes and Regression Line Equation for Annual Rainfall Totals

S/N	Station	a(Intercept)	b(Slope)	Regression Line Equation
1.	Enugu	1657.7	5.84	Y = 1657.7 + 5.84x
2.	Umuahia	2052.3	5.25	Y = 2052.3 + 5.25x

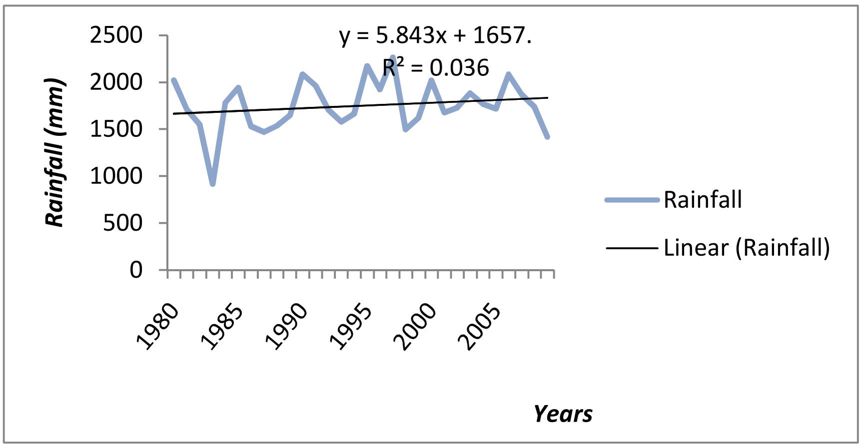
Table 2: Intercepts, Slopes and Regression Line Equation for Mean Annual Temperatures

S/N	Station	a(Intercept)	b(Slope)	Regression Line Equation
1.	Enugu	31.84	0.02	Y = 31.84 + 0.02x
2.	Umuahia	26.37	0.03	Y = 26.37 + 0.03x

The warming trends for Enugu and Umuahia, South-Eastern Nigeria are in agreement with the global trend (IPCC, 2001, United States National Climatic Data Center (USNCDC), 2001 and Ahlenius, 2007, for example). Ordinarily, an increase in temperature will cause water molecules to leave wet surfaces and plant leaves, a process termed evapotranspiration thus increasing the tendency for rain to fall (Meyer, 1996; Chima *et al*., 2009). It is therefore not surprising to find rainfall for the stations sampled having an upward trend, just like their annual mean temperatures.

Derived Savanna in South-Eastern Nigeria

Savanna, an India American name for a grassland area with no forest cover is the largest vegetation type in Nigeria with three major belts Guinea Savanna, Sudan Savanna and Sahel Savanna.

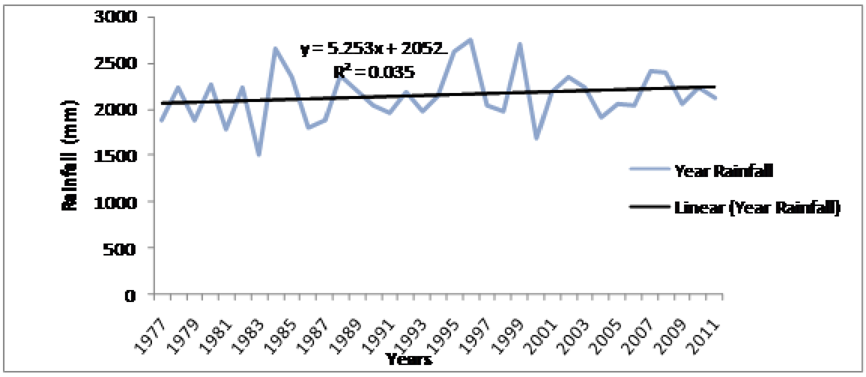


Source: Authors' Fieldwork

Figure 2: Trend of Annual Rainfall Totals over Enugu

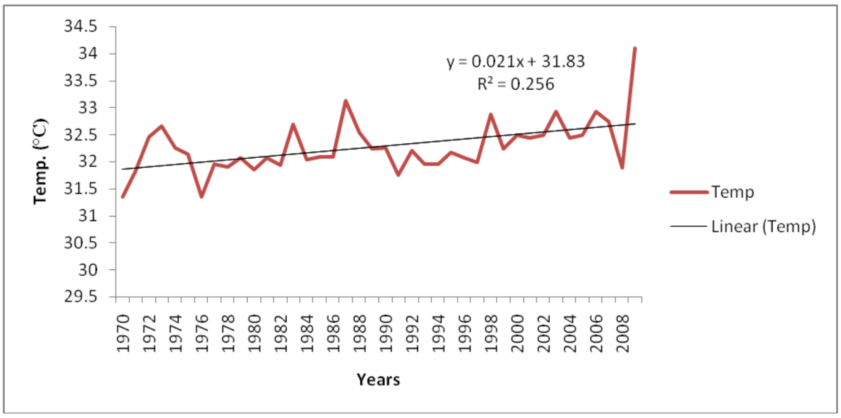
It occupies about 80 percent of the land surface of Nigeria (Nigeria Environmental Study/Action Team (NEST), 1991). These major belts are often times collectively called the "true savanna" as there exists another type of savanna found in the southern fringes of the Guinea Savanna (a true Savanna) and within the high forest belt in Nigeria, especially in geographical South-Eastern Nigeria. This Savanna type is termed "Derived Savanna". Society of American Foresters (2008) defined Derived Savanna as the vegetation existing in sites formerly supporting high forest and having developed through cutting and burning (eg. through shifting cultivation) and being maintained as savanna by annual and frequent grass-fires. Also, tree species here may differ from those of the original high forests. In South-Eastern Nigeria, the Derived savanna covers parts of Abia, Anambra, Cross River, Ebonyi, |Enugu and Imo States reaching 6^0 40' N. About 8 percent (approximately 75,707 sq km) of Nigeria is occupied by this savanna (NEST, 1991). Being that the Derived Savanna is mainly a result of man's activities it is expected that the area covered by it has grown far more than it was in 1991 when

the population of South-Eastern Nigeria was 18, 921, 872 persons (NPC, 1996). The population of the region in 2006 was 30,079,661 (NPC, 2006). And so, the demand for land must have increased too. In other words more shifting cultivation, and by extension, more bush cleaning and burning to feed the populace.



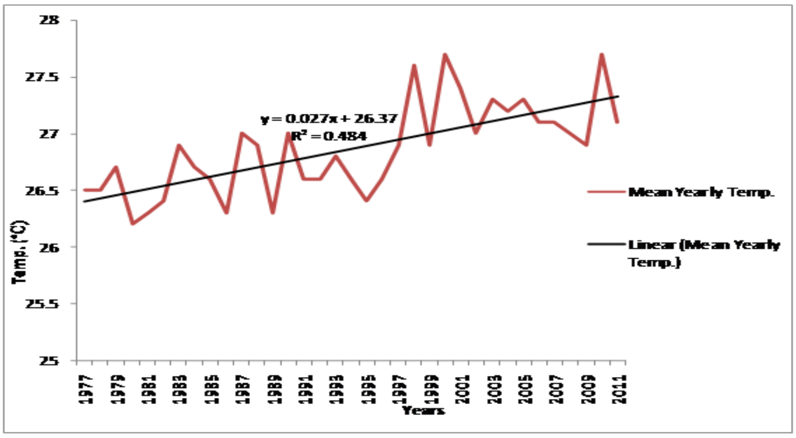
Source: Authors' Fieldwork

Figure 3: Trend of Annual Rainfall Totals over Umuahia



Source: Authors' Fieldwork

Figure 4: Trend of Mean Annual Temperatures over Enugu



Source: Authors' Fieldwork

Figure 5: Trend of Mean Annual Temperatures over Umuahia

Soil Erosion in South-Eastern Nigeria

This subject has received much attention in literature. It is not surprising because of the level of devastation the

soil of South-Eastern Nigeria has experienced by water erosion. Soil erosion, which can be defined as a systematic removal of soil, including plant nutrients from the land surface by various agents of denudation also occurs in several parts of Nigeria under different geological, climatic and soil conditions (Ofomata, 1985). There exist five major types of soil erosion in the country namely, sheet erosion, rill erosion, gully erosion, coastal erosion, and wind erosion. In no part of South-Eastern Nigeria is wind erosion found obviously because of the humid climatic condition of the region as against the arid condition that encourages such erosion. Of concern to us in this study is the gully erosion as it is the most striking on the land surface of South-Eastern Nigeria (Ofomata, 1978, 1980, and 1985) and the most observable, best documented, and most frightful type of erosion in the country (NEST, 1991). Ofomata (1985) observed that more than 1.6 percent of the entire land area of South-Eastern Nigeria is occupies by gullies. Incidentally, this geographical area recorded the highest population density of about 400 persons per km^2 in Nigeria as at 2006 (NPC, 2006).

In 1997, the United Nations Development Programme (UNDP) reported that, out of the 5,700 erosion sites in Nigeria, 4000 of these were in South-Eastern States (Akpokodje *et al.*, 2011) with more than 600 of them active (Igwe, 2012). The number of these sites has certainly increased with increasing population and upward trend in the rainfall of the area. In addition, while there is much awareness in the country about the implications of gully erosion, Nigeria's institutional ability to address them remains weak with population sky rocking, cities expanding and greater number of Nigerians depending on a shrinking pool of arable land (World Bank, 1990). Igwe (2012) lamented that, while the incipient stages of soil erosion through rill and interrill are common and really managed by the people through recommended soil conservation practices, the gully forms have assumed a different dimension such that settlements and scarce arable land are threatened.

Rainfall Trend Derived Savanna and Soil Erosion in South-Eastern Nigeria

The potential of soil erosion, type notwithstanding, is increased if the soil has no or very little vegetative cover of plants and/or crop residues since they protect the soil from raindrop impact and splash (Abegunde *et al.*, 2006). Also, they tend to slow down the movement of surface runoff and allow excess surface water to infiltrate. And the erosion reducing effectiveness of plant and/or residue covers depends on the type, extent and quantity of cover. The significant role of rainfall in soil erosion in the humid tropics, to which South-Eastern Nigeria belongs to, is not in doubt, though it has been fairly studied. For the humid tropics, rainfall is the dominant sub-factor of soil erosion (Ofomata, 1978).

The potential of rainfall in soil erosion in the study area is seen in three different, though related, aspects viz. It gives rise directly to pluvial (splash) erosion because of the impact of raindrops on the ground surface; It equally brings about infiltration where conditions are favourable, such as where the underlying rocks and/or their associated weathered materials are porous and facilitate infiltration; and thirdly, rainfall gives rise to runoff which constitutes a prime candidate in soil erosion system (Ofomata, 1985).

Generally, there is high runoff in South-Eastern Nigeria (Uguru *et al.*, 2011) in the face of an upward trend in the area's rainfall and over an area that is increasingly being turned into a derived savanna.The study of Ezemonye and Emeribe (2012) established that rainfall erosivity (R) indices over South-Eastern Nigeria range from very low to very high. The region's periods of very low erosivity coincided with the dry season months whereas the very high R occurred in the rainy season peak months of June to September.

The development of gullies where the rocks are soft is often so rapid that a gully can start in a rainy night and, within only a few months, grow into a huge gash 100 metres long, over 20 metres wide and 15 metres deep (NEST, 1991). The measured rates of gully growth in South-Eastern Nigeria in one rainy season may be up to 157 metres in length, 50 metres in width, and 5 metres in depth (Abegunde *et al.*, 2006).

Gullies, wherever they occur are environmental disasters that came with it enormous losses of lives arable lands and properties. In many settlements (be them villages, towns or cities) in South-Eastern Nigeria are grappling with challenges arising from the invasion of their communities by gully erosion. According to Ofomata (1985), hundreds of people are directly affected every year within towns and villages by gully erosion, and have to be relocated. Some communities have even been separated because of deep and very wide gullies that may reach in some cases 12 metres deep and more than 1.5 kilometres long (Igwe, 2012).

The major erosion sites in the study area that are notorious for their dimension and destruction are located in the Derived Savanna where vegetation has been cut and burnt as a result of increasing population density and demand for farmland and other developments. These sites are found mainly in Agulu, Nanka, Alor, Nnewi, Ideani Oraukwu, Oko Nkpor, Ekwulobia/Oko, Alo, Uke, Ojokoto/Oba, Udi, Enugu, Ukehe, Amucha, Njaba, Isiukwuato, Ohafia, Abiriba, Arochukwu, Igbere, Ozuitem, Uyo and Calabar (Ofomata, 1978, 1984, 1985 and 1988; Ijioma, 1988, Egboka, 2004; Abegunde *et al*., 2006; and Igwe, 2012).

CONCLUSIONS

The prominent role of rainfall (mainly by way of runoff) in gully erosion has been discussed in this paper. This role is not in doubt for a region like South-Eastern Nigeria which is located in the humid tropics known for its high temperature and heavy rainfall. In addition, this situation is strengthened by the derived savanna vegetation that is found in the northern fringes and within some parts of the study area as scanty vegetation encourages runoff. With the upward trends found in the annual rainfall totals of Enugu and Umuahia, it implies that more runoff will be generated, and by extension more gully formation and the enlargement of existing ones. In other words, the climate of the region is changing as has been found in the two indicators analyzed in this work namely temperature and rainfall.

There is therefore the need for concerted efforts by all and sundry, whether those affected directly or the local, state and federal government. Gully erosion (and any erosion at all) involves some money and time to check or stop which are in most cases beyond what an individual or a community can afford. Governments at local, state and federal levels, international organizations and multinational companies/corporations should be more involved in checking gullies, especially in time to reduce costs checking them and the loss of lives, arable lands and properties. Runoffs, whether from homes or flowing along roads, should be properly channeled to avoid creating rills and inter-rills that may be enlarged over time to form gullies. Improved land use, forest and soil and conservation practices should be adopted by the people.

REFERENCES

1. Abegunle, A.A., Adeyinka, S.A., Olawuni, P.O. and Oluodo, O.A. (2006), “An Assessment of the Socio-Economic Impacts of Soil Erosion in Southern Nigeria”. Shaping the Change, XXIII FIG Congress, Munich, Germany. Pp. 1- 15.
2. Ahlenius, H. (2007): “Climate Feedbacks”. United Nations Environmental Programme/GRID-Arendal.

3. Akpokodje, E.G., Tse, A.C., and Ekeocha, N. (2010): “Gully Erosion geoharzards in Southeastern Nigeria and management implications”. Scientia Africana, Vol. 9 (1), pp. 20-36.
4. Chima, G.N., Nwagbara, M.O. and Ijioma, M.A. (2009). “Rainfall response to dam/irrigation projects in Northern Nigeria”. Global Journal of Social Sciences, Vol. 8 (1) pp. 41-50.
5. Danielson, E.W., Levin, J. and Abram, E. (1998): Meteorology. Boston: WCB/McGraw-Hill.
6. Egboka, B. (2004): “Gully Erosion in Alaigbo”. Osondu News Letter, Online Edition, Vol. 4 (www.osondu.com./abec/erosion index).
7. Ezemonye, M.N. and Emeribe, C.N. (2012): “Rainfall Erosivity in South-Eastern Nigeria”. Ethiopian Journal of Environmental Studies and Management, Vol. 5 (2), pp. 112-122.
8. Hammond, R. and McCullagh, P. (1978): Quantitative Techniques in Geography: An Introduction. London John Wiley.
9. Igwe, C.A. (2012): “Gully Erosion in South-Eastern Nigeria: Role of Soil Properties and Environmental Factors”. Intech-Open Access Company. DOI: 10.5772 51020, Chapter 8.
10. Ijioma, M.A. (1988): “A Conceptual Ecosystem’s Model for Effective Gully Erosion Management: A Case Study of the Onu-Igbere Gully”. Proceedings of the International Symposium on Erosion in South-Eastern Nigeria, pp. 92-97.
11. Intergovernmental Panel on Climate Change (IPCC) (1996): Climate Change 1995. New York: Cambridge Univ. Press.
12. IPCC (2001): Climate Change 2001: The Scientific Basis. New York: Cambridge Univ. Press.
13. IPCC (2007): Climate Change: 2007: The fourth Assessment Report. New York: Cambridge, Univ. Press.
14. Jackson, I.J. (1977): Climate, Water and Agriculture in the Tropics. London: Longman.
15. Linacre,E. (1992):Climate Data and Resources: A Reference and Guide. London. Routledge.
16. Meyer, W.B. (1996): Human Impact on Earth. New York: Cambridge Univ. Press.
17. Monanu, P.C. (1975): “Temperature and Sunshine”. In: G.E.K. Ofomata (Ed) Nigeria in Maps. Eastern States. Benin City: Ethiope Publishers. Pp 16-18.
18. National Population Commission (NPC) (1996): 1991 Population Census of Nigeria. Lagos: NPC.
19. NPC (2006): 2006 Population Census of Nigeria. Abuja: NPC.
20. Nigeria Environmental Study/Action Team (NEST) (1991) Nigeria’s Threatened Environment: A National Profile. Ibadan: NEST.
21. Nwagbara, M.O. (2008): Landover Change in Relation to Climate Change in Northern Nigeria Using GIS Techniques. A Ph.D. Thesis, Department of Geography and Planning, Abia State Univ. Uturu, Nigeria.
22. Obasi, G.O.P. (1992): “Foreword”: In: Anon, Ed., Climate Change: Environment and Development. Geneva: WMO. No. 772, pp. v-ix.

23. Ofomata, G.E.K. (Ed) (1975a): Nigeria in Maps: Eastern States. Benin City: Ethiope Publishers.
24. Ofomata, G.E.K. (1975b): “Factors of Soil erosion in Enugu Area of Nigeria”. Nigeria Geographical Journal, Vol. 8, pp. 45-59.
25. Ofomata, G.E.K. (1978): “Man as a Factor of Soil Erosion in South-Eastern Nigeria”. Eco-Trop., Vol. 1, pp. 145-154.
26. Ofomata, G.E.K. (1980): “Perspectives of environmental deterioration in Nigeria”. The Tropical Environment, Vol. 1, pp. 6-19.
27. Ofomata, G.E.K. (1985): Soil Erosion in Nigeria: The Views of a Geomorphologist. An Innagural Lecture of the Univ. of Nigeria, Nsukka.
28. Ofomata, G.E.K. (1988): “The Management of Soil Erosion Problems in South-Eastern Nigeria”. Proceedings of the International Symposium on Erosion in South-Eastern Nigeria, pp. 3-12.
29. Pidwirny, M. (2004): Fundamentals of Physical Geography. Okonagan: Univ. of British Columbia Press.
30. Society of America in Foresters (2008): Dictionary of Forestry. Dictionary @ safnet.org.
31. Uguru, M.I., Baiyeri, K.P. and Aba, S.C. (2011): “Indicators of Climate Change in the Derived Savannah Niche of Nsukka, South-Eastern Nigeria”. Agro-Science, Vol. 10 (1), pp. 17-26.
32. United States National Climatic Data Center (2001): Global Temperature Changes (1880-2000). Washington D.C.
33. World Bank (1990): Towards the Development of an Environmental Action Plan for Nigeria. Washington D.C.: World Bank, p. 13.